Presidential Address: Scientific Toys
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Reviewed work(s):
Source: *The British Journal for the History of Science*, Vol. 20, No. 4 (Oct., 1987), pp. 377-398
Published by: Cambridge University Press on behalf of The British Society for the History of Science
Stable URL: http://www.jstor.org/stable/4026415
Accessed: 14/12/2012 14:06

BJHS, 1987, **20**, 377–398

PRESIDENTIAL ADDRESS

Scientific Toys

GERARD L'E. TURNER*

Homo ludens is a fundamental but often overlooked aspect when considering how human beings acquire knowledge. All of us, from earliest childhood, learn through play, later called recreation or hobbies. This type of learning is particularly important in discovering how the natural world works, that is, in basic science. Through my study of philosophical instruments it has become clear that the scientific lecture-demonstrations to literate audiences from about 1700 set a pattern for the demonstration of the fundamentals of science that is still with us. Some of the set pieces used by the early lecturers passed into recreational use during the Victorian period, and became toys in the twentieth century.

PART I

The lecture demonstration in experimental philosophy (practical physics in our terms) developed at the very beginning of the eighteenth century in England, and thereafter became of increasing importance, in Britain especially, but also in Holland, elsewhere in Europe, and in New England.[1] The importance lies in the dissemination of scientific knowledge through the different strata of society. It is as though society were a sponge, where the advanced ideas of Newton, Boyle, Hooke were gradually carried by many routes into the mass.

The seventeenth century was a period of rapid change, from Aristotelian physics through Cartesianism to Newtonianism and experimental philosophy. Experiment was a particular feature of the Royal Society at Gresham College, with Hooke one of the

1 See, for example, G.L'E. Turner & T.H. Levere, *Van Marum's Scientific Instruments in Teyler's Museum* (Martinus van Marum: Life and Work, Vol. IV, eds R.J. Forbes *et al.*) (Haarlem: Hollandsche Maatschappij der Wetenschappen, 1973); G.L'E. Turner, 'Apparatus of Science in the Eighteenth Century', *Revista da Universidade de Coimbra,* **26** (1977), 29 pp.; idem, 'The London Trade in Scientific Instrument-Making in the Eighteenth Century', *Vistas in Astronomy,* **20** (1976), pp. 173–182 (Proceedings of the Symposium on the Origins, Achievement and Influence of the Royal Observatory, Greenwich: 1675–1975, 13–18 July 1975); idem, 'The Cabinet of Experimental Philosophy', in: Oliver Impey and Arthur McGregor (eds), *The Origins of Museums: The Cabinet of Curiosities in Sixteenth- and Seventeenth-Century Europe* (1985), chapter 25, pp. 214–222; idem, 'Physical Sciences at Oxford in the Eighteenth Century', in: L.S. Sutherland and L.G. Mitchell (eds), *The History of the University of Oxford,* 1984–, 8 Vols, V, *The Eighteenth Century,* (1986), pp. 659–681.

* Museum of the History of Science, Broad Street, Oxford OX1 3AZ, U.K.

leaders. The air-pump and the large set of experiments that went with it inspired Huygens and others in Holland to build their own apparatus, and, in fact, the first course put on in experimental physics in any university was in 1675 at Leiden. Here De Volder, using Boyle's texts and Samuel Musschenbroek's air-pump, demonstrated the effects of air pressure and the vacuum in a wide variety of ways.[2] The old, closed schemes for total knowledge were eventually rejected for the daring, open-ended experimental methods, which continually added new phenomena, defying unity. It was not so much what was taught in detail, or whether the professors undertook research, but the *fact* of a new approach to problems that released a flood of invention.

The diaries of Samuel Pepys and of John Evelyn testify to the excitement of the experimental vogue at Gresham College. Evelyn says of one occasion: 'I went to the Society where were divers Experiments in Mr Boyls Pneumatique Engine. We put in a snake but could not kill it by exhausting the aire, only made it extreamly sick, but the chick died of Convulsions out right, in a short space.' Here the Fellows were living up to their motto *Nullius in Verba*. Demonstrations of physical effects were soon in demand from novices, and in the first decade of the eighteenth century, lectures and demonstrations were given by a new sort of entrepreneur in the Universities of Oxford and Cambridge and also by scientific instrument makers such as Francis Hauksbee Senior. A worthy successor to Hooke as an experimenter, Hauksbee astounded the Royal Society in 1703 with glow discharges in a partial vacuum, and it is from him that there stemmed the enormous interest in frictional electricity, which was to become one of the greatest of the demonstrators' set pieces.

In the words of a German visitor: 'We saw with amazement Hauksbee's excellent demonstrations and experiments, especially those relating to the nature of light, which were certainly very excellent and curious. We took up the book of experiments that he had published and got him to show us one after another.'[3] The book in question, published in London in 1709, was to be translated into Italian, Dutch and French.[4]

John Desaguliers started to give lecture demonstrations in Oxford in 1710, but he soon transferred to London, and then lectured in other parts of the country and in Holland.[5] This became the pattern: lectures and demonstrations in London, in the coffee houses or in the shops of instrument makers, if sufficiently large; and in the provinces demonstrations by itinerant lecturers, whose apparatus was carted about with them. By January 1712, both Francis Hauksbee Senior and his nephew of the same name were giving extensive courses at their respective premises in London. By January 1714, the

2 Edward G. Ruestow, *Physics at 17th and 18th-Century Leiden: Philosophy and the New Science in the University* (The Hague, 1973), especially pp. 96ff.

3 *Herrn Zacharias Conrad von Uffenbach merkwürdige Reisen durch Niedersachsen Holland und Engelland*, 3 Vols (i, Ulm and Memmingen, 1753; ii, Frankfurt and Leipzig, 1753; iii, Ulm, 1754), ii, 224–225. For a translation of part of this work, see *London in 1710: From the Travels of Zacharias Conrad von Uffenbach*, translated and edited by W.H. Quarrell and M. Mare (London, 1934), quotation from p. 169.

4 Francis Hauksbee [Snr], *Physico-Mechanical Experiments on Various Subjects. Containing an Account of several Surprizing Phenomena Touching Light and Electricity, Producible on the Attrition of Bodies. . . .* (London, 1709).

5 Turner, 'Physical Sciences at Oxford . . .' (footnote 1), pp. 671f; Turner and Levere (footnote 1), pp. 14–15. W.D. Hackmann, 'The Growth of Science in the Netherlands in the Seventeenth and Early Eighteenth centuries', in M.P. Crosland (ed.), *The Emergence of Science in Western Europe* (London, 1975), pp. 89–109.

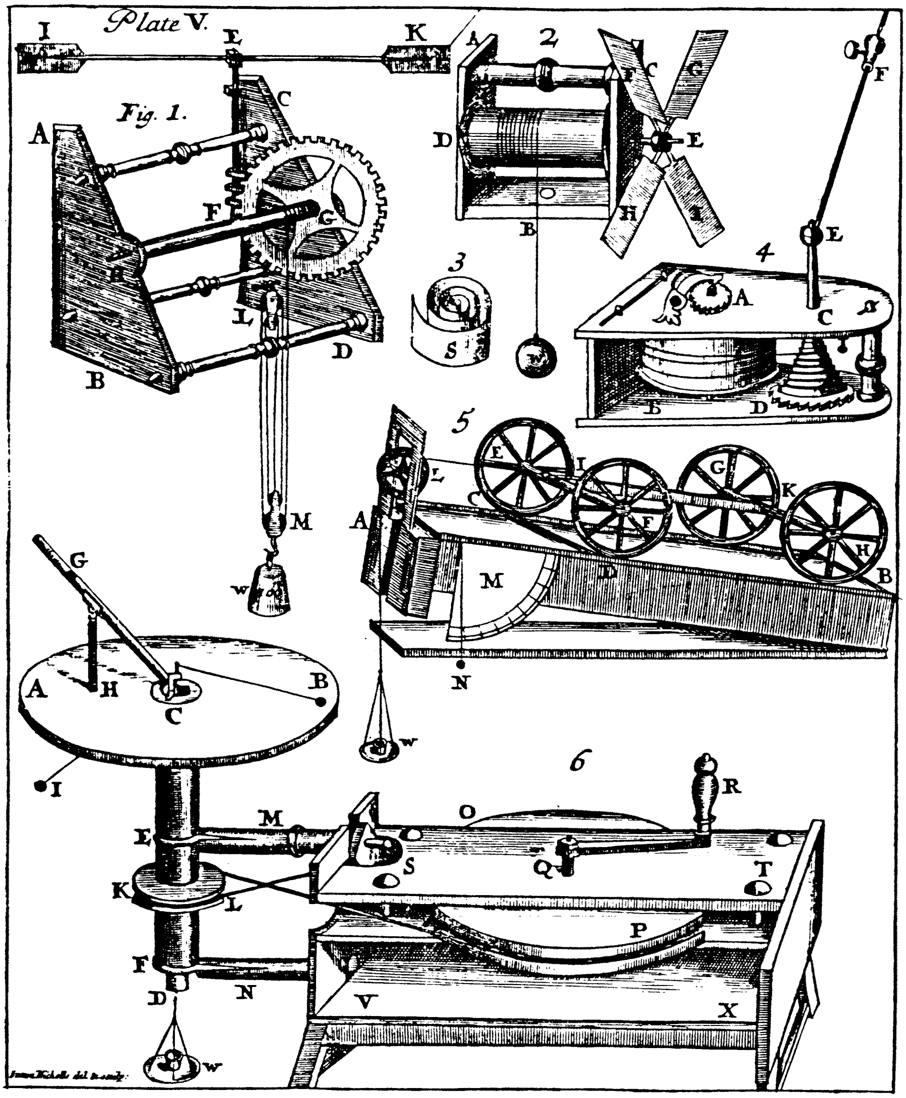


Figure 1. Plate V from the section Mechanicks from the syllabus originally put out by William Whiston, *c.* 1714, and reprinted for use by many later lecturers.

nephew had joined with William Whiston, recently expelled from the Lucasian chair at Cambridge for heresy, to put on a Course of Mechanical, Optical, Hydrostatical and Pneumatical Experiments, the fee being 2½ guineas for 26 days (Fig. 1). This course is of particular significance, because Whiston produced a printed syllabus that was copied by most of the other lecturers during the eighteenth century, setting a pattern not only in England, but in France, Holland and elsewhere.[6]

6 Turner, ibid., p. 673.

Oxford, too, kept a continuity, for after Desaguliers left in 1713, John Whiteside took over the Ashmolean Museum, where he was the fourth Keeper, and James Bradley followed him in 1729. Bradley was Savilian Professor of Astronomy, and from 1742 was also the Astronomer Royal, but it was obviously worth his while to come up to Oxford to lecture on experimental philosophy because his fee was three guineas per head for a course of lectures, and the average attendance at a course was 57. With two courses a year, the income amounted to nearly £400 per annum. Thomas Hornsby took over the lectures in 1763, and in 1790 his apparatus was valued at £375 14*s* 6*d*.[7]

It is well known that men of wealth and position had large cabinets of antiquities and curiosities—Sir Hans Sloane's was the foundation of both sections of the British Museum, but especially the natural history, and George III and the Earl of Bute had very extensive collections of scientific instruments.[8] But the collecting vogue soon spread well down the social scale, as can be seen, for example, from the life of Henry Baker and his friends. Baker is known for his two books popularizing the microscope published during the middle of the eighteenth century.[9] Through the very wide interest in microscopy at the time, and because of poor communications, Baker would be asked by friends to advise on the purchase of instruments, since his home in Fleet Street meant that he was at the centre of that trade. These requests were often inspired by itinerant lecturers. One man, writing from Dublin in 1751 says: 'We have nothing new here but a very usefull Course of Experimental Philosophy by my worthy good friend Dr Stephen Demainbray, in improvements on magnetical discoveries and other subjects.' Some months later came a request for instruments, Demainbray having recommended James Short for telescopes. In 1753, the Dublin correspondent again wrote: 'My good friend Dr Demainbray is now at Toulouse, where he has begun his lectures, from thence he goes, by way of Montpellier, Lyons and to Paris.'[10] The great Parisian popularizer of science in the eighteenth century was the Abbé Nollet, whose *Leçons de Physique* became a standard work, and whose lectures to the French court were famous.

There is no doubt that all these lectures were good for the instrument-making trade, who had thereby unofficial salesmen. One of these, in fact, turned to instrument-making. Benjamin Martin was a vigorous entrepreneur. His first venture was a boarding school at Chichester, where he started his immense output of printed matter with *The Philosophical Grammar*.[11] By 1740 he had become a travelling lecturer in experimental philosophy and soon published a textbook based on the lectures. Martin was one of the

7 Ibid., pp. 672–4.

8 Edward Miller, *That Noble Cabinet: A History of the British Museum* (London, 1973), chapters 1 and 2; J.A. Chaldecott, *Handbook of the King George III Collection of Scientific Instruments* (London, 1951); G.L'E. Turner, 'The Auction Sales of the Earl of Bute's Instruments, 1793', *Annals of Science*, **23** (1967), 213–42.

9 G.L'E. Turner, 'Henry Baker, F.R.S., Founder of the Bakerian Lecture', *Notes and Records of the Royal Society of London*, **29** (1974), 53–79.

10 Most of Henry Baker's correspondence is in John Rylands University Library of Manchester, MS English 19.

11 John R. Millburn, *Benjamin Martin, Author, Instrument-maker, and 'Country Showman'* (Leiden: Noordhoff, 1976); idem, *Benjamin Martin: Supplement* (London, 1986); idem, *Retailer of the Sciences: Benjamin Martin's Scientific Instrument Catalogues, 1756–82* (London, 1986).

earliest to try his luck in supporting a family by taking his transportable apparatus over the poor roads of that period in order to lecture on experimental philosophy in town after town. Reading and Bath were to serve as centres, and from Bath he made tours in the west country and as far north as Chester.

Early in 1756 he opened a shop selling scientific instruments in Fleet Street, just by Crane Court where the Royal Society had its house. Martin's shop soon became well-known for its extensive stock and for Martin's lecture demonstrations, following both the tradition and location of Hauksbee's. Martin also stimulated business by constant publication of catalogues of the instruments he supplied, and pamphlets on a wide range of scientific subjects. He deserves to be remembered as one of the great popularizers of science in the mid-eighteenth century. He was asked to supply instruments to various parts of the world, one of the largest orders being to restock Harvard College after the fire in 1764. The order amounted to £566.[12]

Another travelling practitioner, John Warltire, who styled himself 'Lecturer in Philosophy', had printed in Exeter during the 1760s several editions of his course of lectures, intended chiefly for the use of members of his audience. It included accounts of 'the most necessary instruments used in the Course', and of 'the gradual Improvements of Science.'[13]

Adam Walker (1731–1821), who travelled the north of England using Manchester as a base, had 'Philosophic Apparatus' whose remarkable extent is shown by an advertisement in the *York Courant* of 1772. As well as astronomical apparatus and optical instruments, it included: 'All the mechanical powers, with working Models of various Cranes, Pumps, Water-Mills, Pile-Drivers, Engines, the Centrifugal Machine, and a working Fire-Engine for draining Mines, of the latest Construction.'[14]

From the middle years of the century, there were, indeed, far more travelling lecturers than I can name, and at the centres of population in England and Scotland there were more permanent establishments. The movement became institutionalized in Britain by the founding of the Royal Institution in 1799. In Holland there was no stimulus such as that provided by the Royal Society, and no form of scientific academy before 1752, when the Dutch Society of Science was founded in Haarlem, although in nearby Leiden the university had provided a series of famous professors lecturing in physics.

Martinus van Marum was appointed in 1776 by the town council of Haarlem to lecture in philosophy and mathematics. He had already been asked by a number of people to give private lectures at his home on physics, and his inaugural lecture, held in a concert hall, was on 'The use of Physics in General and for medicine in particular.' Van Marum

12 I. Bernard Cohen, *Some Early Tools of American Science: An Account of the Early Scientific Instruments and Mineralogical and Biological Collections in Harvard University* (Cambridge, Mass., 1950); David P. Wheatland, *The Apparatus of Science at Harvard 1766–1800* (Cambridge, Mass., 1968).

13 John Warltire, *Analysis of a Course of Lectures in Experimental Philosophy; With a Brief Account of the Most Necessary Instruments used in the Course, and the Gradual Improvements of Science: Intended chiefly for the Use of the Author's Audiences*, 5th edn (Exeter, 1767).

14 A.E. Musson and Eric Robinson, *Science and Technology in the Industrial Revolution* (Manchester, 1969), pp. 104–105. Chapter 3 has an excellent account of the travelling lecturers in Britain.

continued to give public lectures well into the nineteenth century, using the large collection of instruments in the Teyler's Museum to illustrate them.[15]

The eighteenth century is usually remembered for many things, from pleasure gardens to Dr Johnson, but not always for the explosive expansion of interest in science among all kinds of people. As James Keir wrote in 1789:

> Nevertheless, the age in which we live, seems to me, of all the periods in history, the most distinguished for the sudden and extensive impulse which the human mind has received, and which has extended its active influence to every object of human pursuits, political, commercial, and philosophical. The diffusion of a general knowledge, and of a taste for science, over all classes of men, in every nation of Europe, or of European origin, seems to be the characteristic feature of the present age . . . in no former age, was ever the light of knowledge so extended, and so generally diffused. Knowledge is not now confined to public schools, or to particular classes of men.[16]

A cultured tourist could not avoid sensing the scientific flavour of eighteenth century London. Not only was there the shrine to Newton in Westminster Abbey to visit, but also the world's most famous instrument makers, and courses on scientific subjects which claimed the attention of Sophie de la Roche and her son. Sophie, a German novelist, visited London in 1786 and kept a diary. Her son made a point of attending the chemistry lectures of Richard Kirwan, a founder member and sometime President of the Irish Academy. Alternatively, in the homes of friends, evenings could be spent among apparatus. Of one such occasion, Sophie wrote: 'our evening passed at physical experiments, which most certainly form part of divine service, showing us as they do the inner qualities of being, and so leading a sensitive soul to increased and rational reverence for its Creator'.[17]

At the other end of the social scale is Alexander Bain. Born in 1810 in a croft in Caithness, he received no secondary education; in 1830 he attended a lecture on light, heat and the electric fluid given at Thurso, and was so fascinated that he stayed behind for after-lecture conversations, before walking thirteen miles home. In later years, Bain said that this lecture was the turning point of his life. He went on to make important inventions on the electric telegraph and in electric clocks.[18]

David Brewster pointed out clearly the practical achievement of the itinerant lecturers when he wrote: 'We must attribute [to them] that general diffusion of scientific knowledge among the practical mechanics of this country, which has, in a great measure, banished those antiquated prejudices and erroneous maxims of construction, that perpetually mislead the unlettered artist'.[19]

15 *Martinus van Marum: Life and Works*, R.J. Forbes, E. Lefebvre and J.D. de Bruijn (eds), 6 Vols, 1969–1976. For the later period, see G.L'E. Turner, 'Teyler's Museum, Haarlem, during the Nineteenth Century', in: P.R. de Clercq (ed.), *Nineteenth-Century Scientific Instruments and their Makers* (Papers presented at the Fourth Scientific Instrument Symposium, Amsterdam 23–26 October 1984) (Amsterdam, 1985), pp. 227–240.

16 J.K. [James Keir], *The First Part of a Dictionary of Chemistry, &c.* (Birmingham, 1789), p. iii.

17 *Sophie in London 1786 being the Diary of Sophie v. la Roche, Translated from the German with an Introductory Essay by Clare Williams* (London, 1933), p. 136.

18 Alexander Bain, *Short History of the Electric Clock* (1852), W.D. Hackmann (ed.), (London, 1973), pp. vii–viii.

19 David Brewster (ed.), *James Ferguson's Lectures on Select Subjects in Mechanics* . . ., 2nd edn, 2 Vols (Edinburgh, 1806), i, p. x; quoted by Musson and Robinson (footnote 14), p. 103.

What they also achieved, unconsciously, was a remarkably consistent pattern of design in demonstration apparatus, running through two and a half centuries. This is most easily shown for mechanics, the study of which goes back to classical times; it is also clear in hydrostatics, hydraulics and pneumatics, and is present, if not so extensive, in optics. Virtually all the demonstrations in mechanics used by Whiston at the premises of Francis Hauksbee in 1714, which are illustrated in six engraved plates of his *Course*, can be identified in the pages of the *Catalogue of Scientific Apparatus* issued by J. J. Griffin and Sons Ltd in 1912. In addition, this catalogue illustrates pieces of equipment of about 1800 showing a strong resemblance to Van Marum's, and it would be possible to pick out from its pages a match for probably well over half of the Teyler's Museum eighteenth-century instruments, covering all the categories. The Baird & Tatlock *Standard Catalogue of Scientific Apparatus* of 1924 also shows the same effect, but with the pieces modernized.

It can come as something of a surprise to see how many of these demonstration pieces are shown by drawings in present-day school text-books, such as A. F. Abbott's *Ordinary Level Physics,* first published by Heinemann Educational Books Ltd in 1963, and since reprinted many times. This is merely an example of the percolation down to younger audiences brought about by the enormous amount of scientific knowledge that needs to be assimilated today by the professional exponent of the subject. From the predominantly middle-aged audience of the eighteenth century, through the undergraduates of the last century and the secondary schoolchild of this century, the process of teaching the basis of science is now continuing into primary schools.

People seek education for a variety of reasons that may include curiosity and entertainment as well as the serious desire to learn. The fact that the new science acquired a broad base of popular interest, as well as knowledge, achieved far-reaching results. The instrument-making trade was so well supported that it was capable of producing new instruments; Nairne and Ramsden are important in this respect. The academies and scientific societies themselves patronized scientific investigation. The lecture-demonstration was institutionalized in mechanics institutes, and was also experienced by many of us in our school-days.

PART II

In the progress of science one can distinguish a high road, with markers such as Galileo, Newton, Lavoisier, Faraday, and a low road, through Ozanam, Montucla, Guyot, Hutton, Pepper, Houdin. One group worked and taught at the frontiers of science, the other followed, to instruct through amusement. Their skill was to show that the strange and fearful can be readily explained, and so they appealed to impressionable adults in the eighteenth century, to youngsters in the nineteenth, and to school-children in the twentieth.

Education and amusement go so closely together that it is not surprising how many of the pieces of demonstration apparatus used in the eighteenth-century lectures were the direct forerunners of toys and amusements made for children and family entertainment in the Victorian period. A child's spinning top is almost as old as play itself, but the demonstration of the gyroscope provides an explanation of the dynamics behind the top's motion, and also that of the Earth. The facts of dynamic motion may be absorbed by a child through watching a gyroscope, or he may simply be fascinated to watch it, and try to make it spin evenly. Other eighteenth-century demonstrations have been reborn in the form of modern toys. The so-called 'Newton's Cradle' derives from percussion balls; the rolling double cone is the forerunner of 'Control-o-Ball', a game where a ball appears to roll up a slope to drop into a series of numbered holes; and the 'Drinking Duck' is based on the thermoscope of Galileo. The way in which yesterday's science so often becomes today's recreation does not make it any the less scientific. Indeed, much scientific, and other, knowledge is absorbed consciously or unconsciously through play.

Throughout the nineteenth century, popular interest in science was stimulated by an apparently endless series of books (see Fig. 2). These reproduced for the ordinary reader the well-established subject-matter of eighteenth-century writers on experimental philosophy, Dutch, English and French. The idea of science as recreation, however, had its origins in the seventeenth century. In 1803, a four-volume work was published entitled *Recreations in Mathematics and Natural Philosophy: containing Amusing Dissertations and Enquiries concerning a Variety of Subjects the most remarkable and Proper to excite Curiosity and Attention to the Whole Range of the Mathematical and Philosophical Sciences,* by Charles Hutton (1737–1823), who was a self-taught mathematics teacher, appointed in 1773 as professor in that subject at the Royal Military Academy at Woolwich. This book was a translation from the French of Jean Etienne Montucla (1725–1799), and he in turn had made a revision and extension of *Recreations mathematiques et physiques . . . ,* by Jacques Ozanam (1640–1717), a private tutor of

Figure 2. Six books on recreational science, by F. Marion (1868); H. E. Roscoe (1871); David Brewster (1883); J. H. Pepper, 8th edn (1880); 4th edn (1877); new edn (1880).

mathematics in Paris. His book, first appearing in 1694, went through eight editions during the eighteenth century, and was also translated. He, too, relied heavily on earlier writers, one of whom, Henry van Etten (a pseudonym) wrote in French a work that was published in London in 1633, under the title *Mathematicall Recreations. Or a Collection of sundrie Problemes, extracted out of the Ancient and Moderne Philosophers.*[20] This book included tricks with coins, dice and cards, mathematical puzzles, and experimental 'wonders' in optics, hydrostatics, and mechanics. The pattern set here can still be discerned 250 years later in *Letters on Natural Magic* (1833), by Sir David Brewster (1781–1868), revised edition London, 1883, and, three generations on, in *Scientific Magic* by Sam Rosenfeld, published in New York in 1959. This series of books perpetuates the common theme of science providing a simple, reasonable explanation for apparently magical or miraculous effects: science, in fact, as the casting-out of superstition and fear.

The nineteenth century had an insatiable appetite for self-made entertainment to be enjoyed by all ages. Scientific demonstrations could provide this, supplying in addition the element of instruction which made amusement respectable.[21] So Hutton had many imitators, including the attractively-named *Philosophical Recreations, or Winter Amusements: A Collection of Entertaining and Surprising Experiments* (*c.* 1820).[22] Other books were aimed directly at the young, the pill of learning being sugared by the use of such words as 'magic', 'fairyland' and 'playbook'. Examples of this genre are *Philosophy in Sport Made Science in Earnest,* published in 1827 by John Ayrton Paris, the eighth edition of which appeared in 1857, and *The Fairyland Tales of Science* (1889), with chapters on 'Formation of Dew,' 'The Rainbow,' 'Lightning', and 'Micro-organisms in Water'.

It was with this sort of encouragement that science as instruction and amusement found its way into the home and so into the consciousness of the majority of people from an early age. Scientific toys can conveniently be considered within the categories chosen by the demonstration-lecturers of the preceding century, that included mechanics, hydrostatics, optics, electricity, magnetism, and pneumatics.

Some of the travelling lecturers specialized in astronomy, using geared models of the solar system. Such a model was usually given the name 'orrery', and though some orreries of the eighteenth century are both expensive and elaborate, using clockwork, simple wooden versions were also made, incorporating a crank handle to rotate the wire arms holding balls to represent the planets. Chemistry was usually taught separately from the other topics which are now grouped together as 'physics', and the apparatus and materials used for chemical experiments were provided by specialist suppliers. By the

20 For Van Etten and his precursors, see Trevor H. Hall, *Mathematicall Recreations: An Exercise in Seventeenth-Century Bibliography* (Leeds Studies in Bibliography and Textural Criticism) (Leeds), 1969. The theme is continued by the Bishop of Chester, John Wilkins, *Mathematical Magick: Or, the Wonders that may be performed by Mechanical Geometry* (London, 1680); Jean-Antoine Nollet, *L'Art des Expériences, ou Avis aux Amateurs de la Physique* . . . 3 Vols (Paris, 1770); Monsieur Guyot, *Nouvelles Récréations physique et mathématiques,* . . . , 3 Vols (Paris, 1786); Edouard Lucas, *Récréations mathématiques*, 4 Vols (Paris, 1883–1894); Robert Houdin, *Magie et Physique amusante* (Paris, 1898).

21 For an illustrated essay, see G.L'E. Turner, *Nineteenth-Century Scientific Instruments* (London, 1983), chapter 16, 'Recreational Science'.

22 Anonymous; no date, but frontispiece is watermarked 1820.

1840s, chemistry sets for children were being advertised and they continued to be popular well into the present century, with little change in the ingredients. The popularity of natural history specimens, minerals, fossils, seeds, shells, spread from adults to the young, and small chests containing sea-shells and other such items were marketed for the delight and instruction of children.

Two of the most ancient of toys are the whip-top and the hoop. To these can be added the yo-yo, a flat reel on which a length of fine string is wound, with a loop at the loose end that fits over the player's middle finger. The reel is then thrown lightly from the hand towards the ground, and will return as the string recoils itself. The winding-up process acts against the force of gravity through the continuing rotational momentum from the downward motion. The name 'yo-yo' derives from the 1932 craze for this toy, but under a variety of names it dates back at least to the classical Greek period (Fig. 3). All these three traditional playthings can be categorized as mechanical, in that they display the principle of inertia, their stability depending on conservation of momentum (Fig. 4). Tops can be made of wood, bone, or ivory; there are yo-yos from the Regency period made of ivory, elaborately carved on a lathe, but most nineteenth-century examples are made of wood. By 1820, another inertial toy had become sufficiently popular to be described in a book of games: the diablo, or 'devil on two sticks'. This consisted of a double cone rotated by a string held between two sticks. The diablo only retains its stability in the air when thrown up if it is first made to rotate rapidly by rolling on the cord between the sticks—an effect similar to that of the gyroscope. This instrument too found its way into the playroom after its dynamics had been the subject of mathematical treatises.

Anthropomorphic toys, or life-like human figures, often made use of physical forces to produce their special effects. One of the oldest balance toys is the tumbler, usually the figure of a clown, heavily weighted at the base, so that it always rights itself when pushed over, showing a gravitational effect. The figure of an acrobat could be balanced on a point

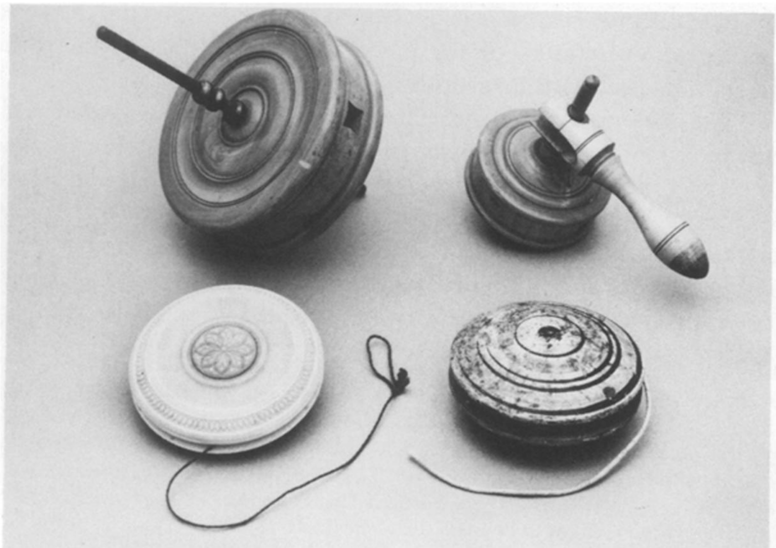


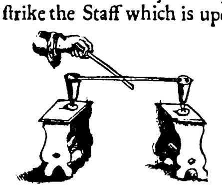
Figure 3. Two boxwood tops and two yo-yos, one in ivory and one in wood; late nineteenth century.

12 Mathematical Recreation.

PROBLEM IV.

How to break a Staff which is laid upon two Glaſſes full of Water, without breaking the Glaſſes, or ſpilling the Water; or upon two Reeds or Straws, without breaking of them.

FIrſt, place the Glaſſes which are full of Water upon two Joynt Stools, or ſuch like, the one as high as the other from the ground, and diſtant one from another by two or three foot, then place the ends of the Staff upon the edges of the two Glaſſes, ſo that they be ſharp : this done, with all the force you can, with another Staff ſtrike the Staff which is upon the two Glaſſes in



the middle, and it will break without breaking the Glaſſes, or ſpilling the Water.

In like manner may you do upon two Reeds, held with your hands in the Air without breaking them: Thence Kitchin-Boys often break Bones of Mutton upon their hand, or with a Napkin, without any hurt, in onely ſtriking upon the middle of the Bone with a Knife.

Now

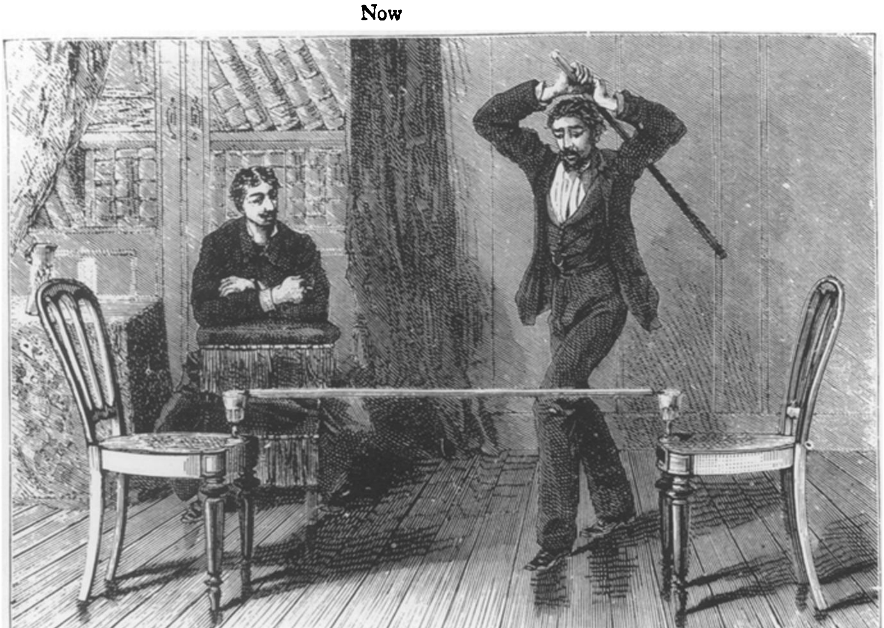


Figure 4. Experiment to show the principle of inertia. (above) Henry van Etten, *Mathematical Recreations* (London, 1674), p. 12. (below) Gaston Tissandier, *Popular Scientific Recreations in Natural Philosophy, Astronomy, Geology, Chemistry, etc*, English translation (London, 1882), p. 36.

because he carried a curved bar with counterweights at each end, so that the centre of gravity of the combination was brought below the point of support. A mobile centre of gravity, provided by a quantity of mercury placed in the hollow, flexible body of an acrobat, enabled the figure to somersault down a flight of steps. Another version placed the mercury in hollow bars held by two acrobats, who somersaulted over each other. Toy acrobats could also be attached to a rod which then rolled down gently-inclined parallel bars in a frame, causing the figures to rotate (Fig. 5). Yet another gravitational effect was demonstrated by the toy figure with pivoted legs and leaded feet which, when placed on a slope, performed a shuffling walk.

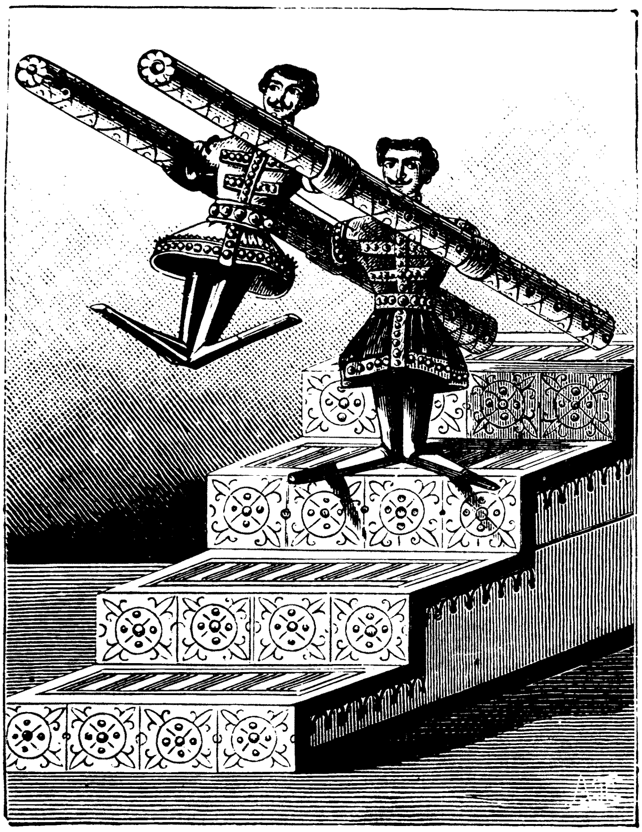


Figure 5. Gravity toy. The puppets descend the steps because the side bars contain mercury, the displacement of which alters the centre of gravity. Tissandier, p. 30.

The operation of the lever found its way into the playroom in the form of lazy tongs, either with a joker's head at the end, or a parade of wooden soldiers at the joints. Wooden birds perched on a flat board are given animation, moving to peck in turn as a pendulum weight swings below the board. Centrifugal force is used in the toy consisting of a circular wire track with a handle, on the inner side of which a ball can be made to roll at speed, and stay in position, by a small circular motion of the track.

During the seventeenth and eighteenth centuries, the behaviour of water was seriously studied, and the knowledge put to use for many practical and ornamental purposes. The great houses and public gardens of the period were replete with fountains, and models of those made to the pattern of Hero of Alexandria were used by demonstration-lecturers. Two other of their pieces of apparatus became playthings. One was designed to show the effect of buoyancy and specific gravity, and consisted of tiny figures, usually imps (Fig. 6), blown from glass to have a specific gravity close to that of water. If these were placed in a jar of water with a membrane over the top, varying pressure on the membrane would make the figures rise and sink. The other device was known as the Tantalus beaker, the figure of a man being placed in a glass goblet, into which water is gradually poured. When the water reached the level of his mouth, it was slowly syphoned out by means of a tube secreted in the figure. During the nineteenth century, with the improvement of domestic plumbing, the large, fixed bath was to be found in an increasing number of homes, and the first bath toys appeared. Model boats were powered by camphor pellets, the drive produced by the surface tension of the water-camphor solution.

Sight is man's chief sense, and optics, therefore, the chief provider of illusions that were often thought to be magical. The simplest optical toys are those which make use of mirrors. Anamorphic pictures, or distorted drawings, have been popular since the sixteenth century, the trick being that the distortion is rectified by a conical or cylindrical

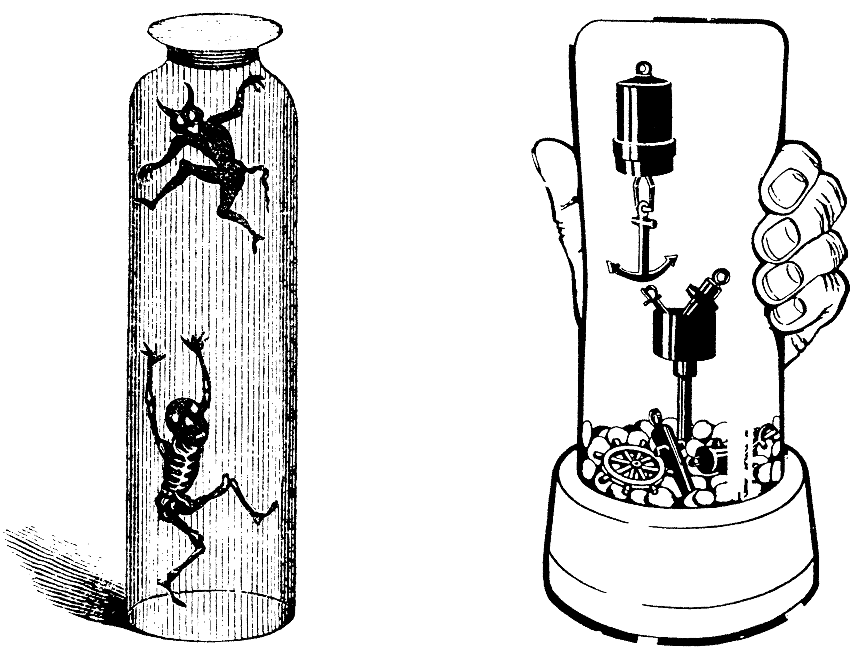


Figure 6. Buoyancy demonstration. Bottle imps, or Cartesian divers. (a) illustration from John Ayrton Paris, *Philosophy in Sport made Science in Earnest,* 8th edn (London, 1857), p. 188. (b) Dyna-Diver, Invicta Plastics Ltd, 1973.

mirror of glass or metal.[23] In the early nineteenth century, a toy of enormous popularity was invented by David Brewster. This was the *Kaleidoscope* (beautiful-form viewer), patented in 1817 and made under licence by several instrument makers. Over 200,000 were sold in London and Paris within a few months of its production.[24]

One of the oldest of all optical tricks was that employed by the so-called *camera obscura*. This device, originally quite literally a darkened room, was produced, from the eighteenth century on, in box form as a recreational device, complete with pin-hole, ground glass screen and lens. To create the illusion of seeing pictured scenes with the vivid, three-dimensional effect of actual vision, mirrors and lenses were used in a number of ways.

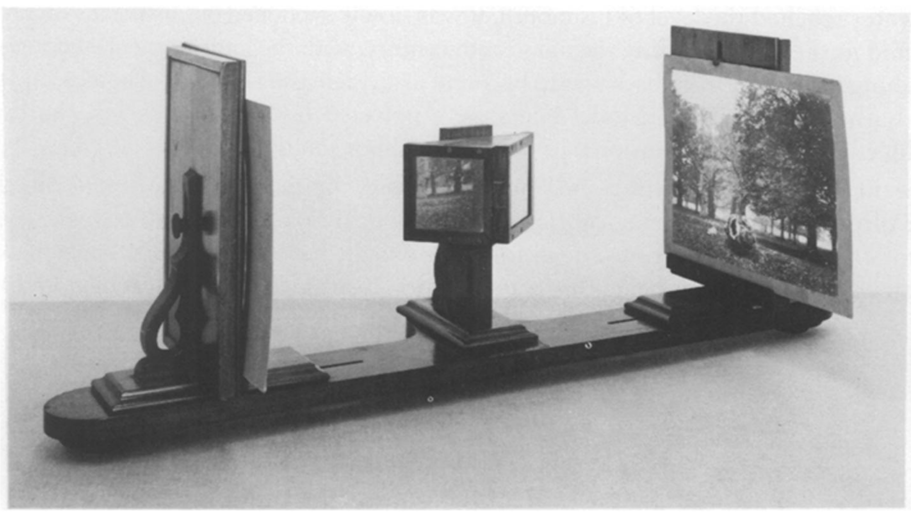


Figure 7. Wheatstone stereo viewer, first published in 1838. Courtesy of the Trustees of the Science Museum; inventory number 1884–1886.

The *Zograscope,* or 'optical diagonal machine', was made for viewing prints of landscapes, thereby endeavouring to create an illusion of seeing the landscape directly.[25] The origins of this device are obscure, but it is thought to have first appeared in Paris early in the eighteenth century. To counter the reversal of the image brought about by the mirror, the prints had to be made reversed. Such reversed prints were certainly on sale in 1753, and the device continued to be popular into the nineteenth century. The *Stereoscope* (solid-view) is an instrument intended to produce a single mental image, giving the impression of solidity as in ordinary vision, from two pictures of the same scene. The original form, the reflecting stereoscope, was invented by Charles Wheatstone in the 1830s (Fig. 7); the user looks at two mirrors set in a 'V', which reflect pictures placed at

23 Fred Leeman, *Anamorfosen: Een spel met waarneming, schijn en werklijkheid* (Amsterdam, 1975). For a bibliography on optical instruments, see G.L'E. Turner, *Essays on the History of the Microscope* (Oxford, 1980), chapter 2, 'The History of Optical Instruments: A Brief Survey of Sources and Modern Studies'.

24 A.D. Morrison-Low, 'Brewster and Scientific Instruments', in *'Martyr of Science': Sir David Brewster, 1781–1868,* A.D. Morrison-Low and J.R.R. Christie (eds) (Edinburgh, 1984), pp. 59–65 (p. 61). This paper also deals with the stereoscope.

25 J.A. Chaldecott, 'The Zograscope or Optical Diagonal Machine', *Annals of Science*, 9 (1953), 315–322.

the sides. The refracting or lenticular form of the device was invented by David Brewster, and consists of two tubes containing lenses through which the two pictures are seen, one by each eye. Brewster first announced his invention in 1849, but could find no British optician willing to manufacture it, so he went to the Parisian firm of Duboscq, who made and exhibited the first stereoscope at the Great Exhibition in 1851. Queen Victoria saw it there and was amused by the optical illusion, giving the instrument a drawing-room vogue which produced sales comparable to those of the kaleidoscope.

A whole range of optical illusion devices which became popular during the nineteenth century are based for their effect on the phenomenon of persistence of vision. These devices, which for some reason attracted elaborate Greek names, were the direct forerunners of the modern cinema, and the first was actually invented by a leading medical man to illustrate his research into persistence of vision.[26] Dr John Ayrton Paris (1785–1856), who became president of the Royal College of Physicians in 1884, and was the author of *Philosophy in Sport,* first demonstrated his invention in 1825. The *Thaumatrope* (wonder-turner) consists of a card disk with two different figures drawn on the two sides, which are apparently combined into one when the disk is rotated rapidly (Fig. 8). An impression made on the retina of the eye lasts between 1/50th and 1/30th of a second after the object that produced it is withdrawn.

Figure 8. The first illustration of a Thaumatrope, invented by John Ayrton Paris, and described in his book *Philosophy in Sport* (London, 1827), vol. 3, p. 1. Paris, a doctor, realized that the retina of the eye retains an image for about 1/30th of a second.

The *Phenakistoscope* was invented by Professor J. A. F. Plateau of Brussels, and almost simultaneously by Professor S. Stampfer of Vienna, who called his instrument the *Stroboscope.* A disk with figures arranged radially representing a moving object in successive positions is spun on an axle. Reflections of the figures in a mirror are viewed by looking through radial slits cut in the disk. Persistence of vision produces the impression of actual motion. This invention was the first of all the later and more complicated forms of motion picture. The *Zoetrope,* or Wheel of Life, a development of the Phenakisticope, was invented by W. G. Horner of Bristol in 1834, but it was not marketed until 1867. The device consists of a slot-pierced drum which revolves horizontally on a pivot. Inside the drum below the slots is a paper band on which are drawn pictures in various stages of movement. When the drum is set in motion and the figures are viewed through the slots an impression of action is given. The French *Praxinoscope*, an improvement on the Zoetrope, was invented and patented in 1877 by Professor Emile Reynaud. Instead of slots to peer through there are rectangular mirrors set round an inner drum which reflect the image drawn on the paper strip fixed to the inside of the outer drum. When set in motion the impression of movement is smoother and less fatiguing to the eyes than is the case with earlier devices.

The *Choreutoscope* was one of the first attempts to project a moving figure on to a screen. This device was invented in 1866 by Lionel S. Beale (1828–1906), physician and microscopist, and assistant to Sir Henry Acland at Oxford in 1847. Intermittent movement and the shutter action are achieved by means of a circular disc carrying a pin attached to a handle. As the disc revolves the pin engages with a notch on the slide, moving it on by the space of one picture and at the same time raising the shutter. This arrangement is a forerunner of the Maltese Cross device used in cinematography.

Of the two most important optical scientific instruments, the microscope and the telescope, it was the former, because of its convenient size, which became more popular with the layman. Through it, all manner of common but minute objects could be examined: insects, hairs, seeds, minerals, plant organs. Its use encouraged the systematic collection of material from ponds, rivers and hedgerows, and fitted in excellently with the nineteenth-century vogue for the study of natural history. By the 1860s there were microscopes to suit every taste and pocket, from the simple bead of Canada balsam in a

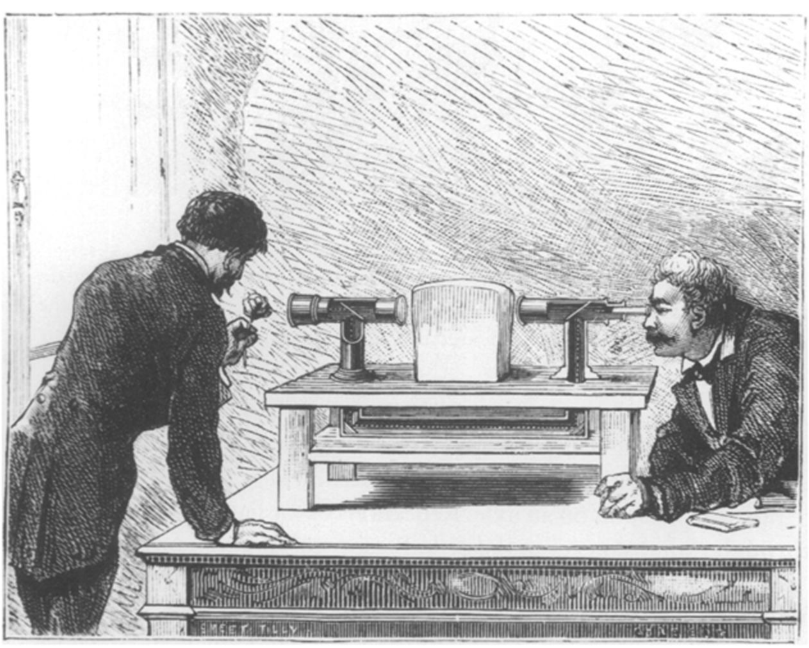


Figure 9. A 'divided telescope', an optical illusion dependent on mirrors, apparently seeing through a stone. Tissandier, p. 135.

piece of card, costing a penny, to elaborate and expensive boxed microscope kits in mahogany boxes. Many books were produced for the amateur microscopist, from the age of ten upwards (Fig. 10). An example of their continuing popularity was a small volume entitled *Common Objects of the Microscope,* first published by the Reverend J. G. Wood in 1861, which was still in print in 1949.

Figure 10. A boy with a compound microscope, the most popular of the scientific recreations in the second half of the nineteenth-century. Fulgence Marion, *L'Optique* (Paris, 1867), p. 130.

The recreational use of electricity goes back far beyond the modern battery-powered cars and train-sets. Natural philosophers of the eighteenth century investigated the production of static electricity from friction, using vast machines of brass and plate glass (Fig. 11). These machines, when scaled down for use in the home, could create amusing

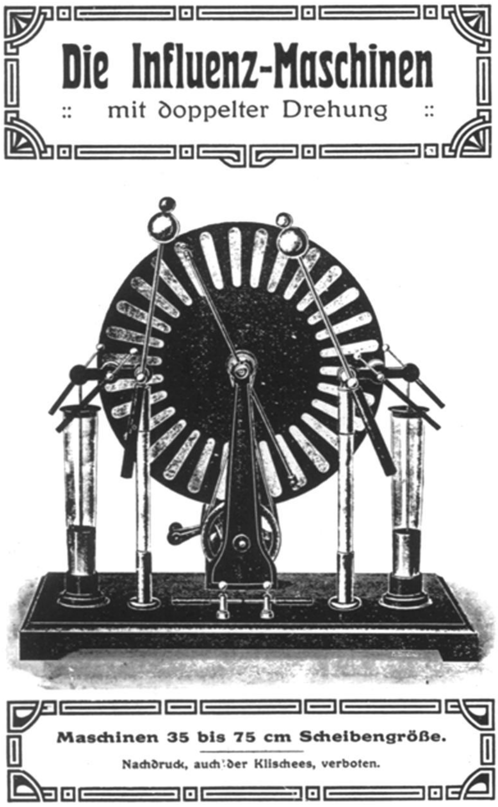


Figure 11. A Wimshurst machine intended for young boys, about 1900.

and startling effects; therefore, from about 1800, kits were sold that included, as well as the manually-cranked machine, pith puppets that could be made to dance, a model head with long hair that could stand on end, and electrically-operated chimes. Another electrical toy was the thunder house, which demonstrated the effect of lightning, the walls being made to collapse in response to an electric shock. Other pieces of apparatus which later appeared as playthings were the Geissler tube and the Volta electric pistol. In the latter part of the century, miniature versions of the Wimshurst electrical machine and the telephone were sold as toys. In the 1830s, the electric generator was developed by Michael Faraday, and later toy dynamos were made to be driven by model steam-engines, the small current generated causing an electric lamp to light up. The origin of many moving toys of the nineteenth and twentieth centuries may be traced to models made for serious design and demonstration purposes; examples are engines, carriages, and ships.

In the nineteenth century, horseshoe magnets were popular toys, and another game consisted of a peg on which circular magnets with a hole in the middle could be positioned, either fitting together in one polar orientation, or holding mysteriously apart in the other. The use of secreted magnets is found in a number of games of the period. In one of these, there is a picture of an artist painting at an easel, and a group of scenes is provided, each containing a magnet in a different position. When one of the scenes is positioned, a miniature of it appears on the artist's easel, brought into place by the attraction of another small magnet in a rotating disc which carries the sequence of scenes in miniature. Magnetic attraction is used in another game to teach grammar by question and answer. As a particular question is positioned, the magnetic pointer moves to indicate the correct answer.

Air power and heat were investigated and put to serious use during the eighteenth and nineteenth centuries, following the invention of the air-pump in the seventeenth century, and, in 1712, the building of the first effective steam-engine by Thomas Newcomen. Windmills, kites and air balloons naturally found their way into the playroom. The power of an up-draught of hot air, used to turn a jack in large kitchens, gave rise to a toy which incorporated a paddle wheel, turned by hot air from a gas jet, and a cranked axle that activated little figures. Popular toys which demonstrated air pressure were a ball balanced on a jet of air blown through a tube by the mouth, and the long bladder or paper tube which uncoils when inflated. Steam power was at first used as the motive power for toy trains (Fig. 12), but it was hazardous, particularly for moving models, and clockwork gradually took over for most moving toys.

Finally, there is a group of recreational objects that we may call the intellectual's toys; Rubik's Cube is a recent popular example. Many items in this group are topological puzzles, starting with string figures which are very ancient, and to which Rouse Ball devoted a chapter in the ninth edition of his *Mathematical Recreations* (1920).[27] There are many puzzles that involve releasing a nut or ring from a string without undoing a knot—or rather, an apparent knot, because these puzzles depend on there being no real knot—as with Houdini escaping from his chains, or in the trick of removing your waistcoat without taking off your jacket. There are sets of these topological puzzles in carved ivory from around 1800, and they occur again in the early 1900s and continue today.

Possibly the most recherché of these topological puzzles is that invented by Sir William Rowan Hamilton. It was published in London in 1859 by John Jaques & Son, the well-known games firm, with the title: *The Travellers Dodecahedron, or a voyage around the world, and the Icosian Game, invented by Sir William Rowan Hamilton, Royal Astronomer of Ireland; forming a new and highly amusing game for the drawing room, particularly interesting to students in mathematics of illustrating the principles of the Icosian Calculus* (Fig. 13). The game exists in at least one extant example, which I saw about twenty years ago. You take a regular dodecahedron and give to each of the 20 angular points the name of a town. The idea is then to move from town to town along the 30 edges, and you have to pass once and only once through each town. A more practical version opened out the solid on to a plane. Pegs or counters are used to mark each town when visited.[28] Hamilton explained his game at the 1857 meeting in Dublin of the British Association.

26 For pre-cinema toys, see C.W. Ceram, *Archaeology of the Cinema* (London, 1965).

27 W.W. Rouse Ball, *Mathematical Recreations and Problems of Past and Present Times* (London, 1892). String figures are in the 9th and 10th editions, and also in his separate publication, *String Figures* (Cambridge, 1920; reprinted New York, 1969).

28 A fine, wooden example of the icosian game is in the library of the Royal Irish Academy, Dublin (see Figure 13). For an explanation of the Icosian Game, see Lucas (footnote 20), ii, 210–222; and Rouse Ball *Mathematical Recreations* (footnote 27), any edition.

I have outlined the development of scientific recreations from the cabinet of experimental philosophy and its demonstrations to the nineteenth century, with its interest in philosophy in sport. At this point there is a division to be discerned between the

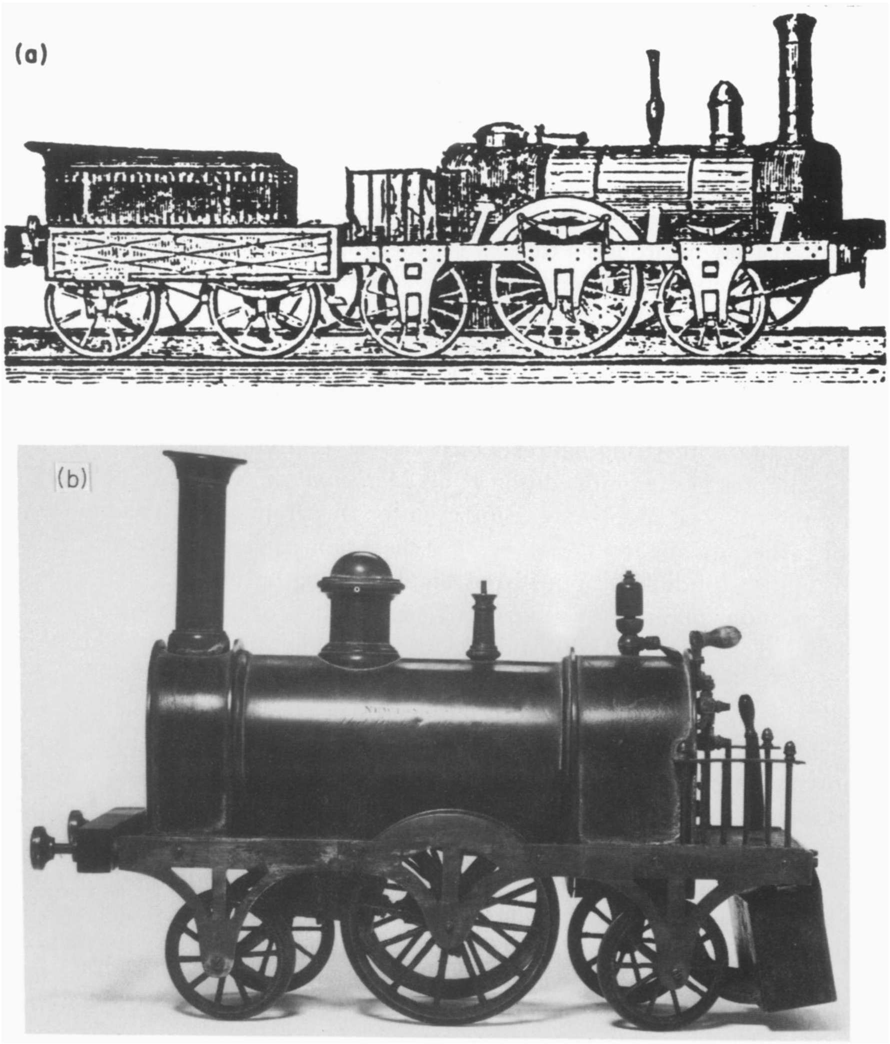


Figure 12. The model steam locomotive was used as a laboratory demonstration from its earliest days, as had been the Newcomen engine and the Watt beam engine before it. (a) A model sold for £2. 2s., *Catalogue of Philosophical Apparatus and Instruments manufactured and sold by Newton & Co., . . . 3 Fleet St., Temple Bar, London, E.C.*, 32nd edn (London, 1904), p. 126. (b) A demonstration locomotive signed: NEWTON & CO., *3 Fleet Street, Temple Bar, LONDON*, sold by Sotheby's, 3 October 1984, lot 422. Photograph courtesy of Sotheby, Parke Bernet & Co, 34/35 New Bond Street, London, W1.

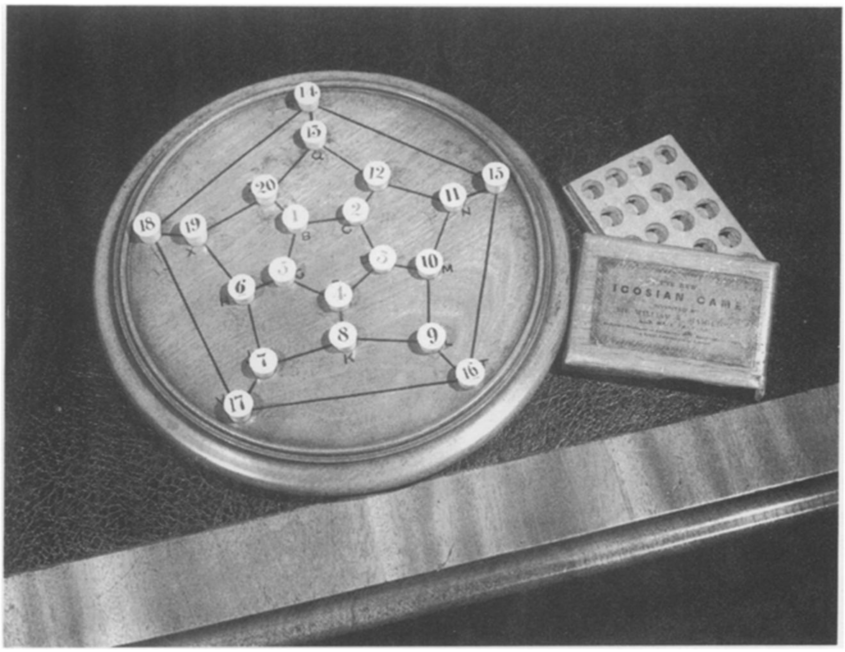


Figure 13. Sir William Rowan Hamilton's Icosian Game, as made and sold by John Jaques & Son, London, 1859. Courtesy of the Royal Irish Academy, Dublin.

large, dramatic displays of scientific effects, intended mainly for adults (such as that at the Royal Polytechnic Institute, the first science centre, opened in 1838 at London),[29] and toys and playthings intended for use in the home.

In the early part of the present century, the makers of scientific toys directed their attention mainly to the home and to children between the ages of ten and fifteen. This trend continues today, aimed at an even earlier age, with the educational toys produced by such specialist firms as Early Learning, whose catalogues contain many examples of the toys described above, now made in plastic. Only in the mid-twentieth century have we seen the reappearance of the large-scale display of scientific effects, as in the Palais de la Découverte in Paris and the Exploratorium in California. Others may be found in Toronto, Barcelona, Bombay and in the Science Museum, London, with its new 'Launch Pad'. These, too, are largely aimed at schoolchildren, and have a didactic educational purpose. In conclusion, I wish to query whether the science centre and its attempt to appeal to *homo ludens* is entirely satisfactory.

The science centre is threatening to take over from the older type of science museum, which displays groups of single types of scientific instrument—astrolabes, microscopes, navigational instruments, chemical apparatus—each group showing examples from the

29 R.F. Cane, 'John H. Pepper—Analyst and Rainmaker', *The Royal Historical Society of Queensland*, **9**, no. 6 (1974–1975), pp. 116–133 (p. 117); Richard D. Altick, *The Shows of London* (Cambridge, Mass., 1978), p. 382.

earliest to the latest in chronological order. This is the traditional science museum display, and in research museums very large groups of a single type of instrument will be on display or in store. This kind of museum is important for the scholar and the enthusiast, but for most people may prove confusing or even boring. Less dense, more obviously artistic displays of old instruments have been attempted, but modern museum thinking about scientific artefacts has tended to regard the old static displays of historic instruments as outmoded, and to concentrate on models, graphics, and button-pushing. There is, indeed, an important dimension missing in the traditional science museum, for generally the displays are not related to the periods in which the artefacts were manufactured and used. But the science centre shows only the principles of science, not how science itself has developed. In fact, in both cases, the historical element is excluded, which would reveal the dependence on economic and social factors and on the transmission of craft skills. Science was born in Western Europe, and is the mainspring of modern society. To ignore its historical origins is to leave a huge vacuum in modern education. What is missing in the science centre and in the old-style science museum, is the time machine effect that is so evocative in the Teyler's Museum, Haarlem, in the seminary at Kremsmunster in Austria, in the period rooms of the Victoria & Albert Museum, and in the period streets recreated in York City Museum. What is needed to counterbalance the science centre and to make sensible use of the enormous resources for historical studies in our technical museums is the display and study of scientific artefacts by period. To neglect this approach would be to cut off our roots. As Sir Arthur Bryant put it: 'The key to a nation's future is in her past. A nation that loses it has no future'.[30]

30 Arthur Bryant, *English Saga (1840–1940)* (London, 1940), p. xi.